Construction and Building Materials 111 (2016) 482–487

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Testing the effectiveness of protective coatings on traditional bricks

M. Stefanidou *, A. Karozou

Lab. of Building Materials, Dept. of Civil Engineering, Aristotle University of Thessaloniki, PO Box: 482, 54124 Thessaloniki, Greece

HIGHLIGHTS

- Manually produced bricks were fired at temperatures below 900 °C and tested by the immersion technique.
- Hydrophobicity achieved by linseed oil decreased porosity and capillary absorption.
- Silane/siloxane solutions formed hydrophobic surface which did not remain after the ageing tests.
- Alkosiloxanes offered the highest protection in bricks and presented high penetrability.
- Nano-silica had a positive role in all the solutions tested as the surface roughness was increased.

ARTICLE INFO

Article history:
Received 16 July 2015
Received in revised form 8 January 2016
Accepted 22 February 2016
Available online 21 March 2016

Keywords:
Traditional bricks
Nano-silica
Linseed oil
Alkosiloxanes
Impregnation
Ageing

ABSTRACT

For millenniums, bricks were the main building material for the load-bearing structural elements of constructions. They were produced manually and they were fired at low temperature. They also present low apparent specific density, high absorption, high surface roughness and relatively low compressive strength. Nowadays, bricks used for restoration works should be compatible to the old ones. As the existing line of modern brick manufacturing is far from the above mentioned criteria, the way to solve the problem is to manually produce these special building materials which render them expensive and laborious. Additionally, their high porosity and soft nature make them easily deteriorated by different environmental conditions. The protection of traditional bricks is an important step towards their durability and a challenge especially nowadays where nanotechnology has been proven efficient when it is incorporated in coatings for building materials.

In the present paper, hand-made brick samples were treated with different coatings by the technique of total immersion. The solutions tested were both traditional such as linseed oil but also silanes and alkosiloxanes both neat and nano-modified. In order to compare the physical properties of the treated bricks, parameters like capillarity, porosity, absorption and durability have been tested. It was concluded that silica nano-particles and micro-clay enrichment of alkosiloxane was the most sufficient way to protect those special building materials.

1. Introduction

Traditional building materials, such as bricks and mortars, which constitute the main parts of masonry structures are highly porous. Porosity is a key factor for the durability of these materials as it allows the permeability to water vapor; thus the water retention in the structure is low [1,2]. In this way, the accumulation of soluble salts is restricted and the materials dry quickly [3]. As water, in its different forms, is responsible for the main pathology symptoms that building materials suffer, from mould growth and surface scaling up to strength reduction, detachments and material loss, the research to efficiently protect these materials without altering their characteristics is of high importance [4]. In special structures, such as aqueducts and baths where water proofing properties were necessary for the building materials, ancient masons combined the appropriate materials in order to achieve hydrophobic properties [5,6] or they applied special techniques such as strong compaction and multi-layer application, especially in renders [7]. In other cases, mortars have been coated with organic oils or organic wax/oil additives. Additionally, the incorporation of organic compounds into the mortar recipes as additives is well-known for improving the cohesiveness of the matrix [8,9]. The hydrophobic properties of linseed oil have been widely tested lately with positive results as the capillary absorption and

* Corresponding author.
E-mail addresses: stefan@civil.auth.gr (M. Stefanidou), aspasiks@hotmail.com (A. Karozou).

http://dx.doi.org/10.1016/j.conbuildmat.2016.02.114
0950-0618/

protection from salts is concerned [10,11]. Hydrophobic lime plasters were customarily produced in Morocco using ''tadelakt technique'' where the traditional application includes polishing with river stone and treatment with oleic acid in the form of olive oil soap to acquire its final appearance and water resistance [12]. Using clay in order to protect constructions from water was also a common practice [13]. Their hydrophilic nature tends to absorb water, preventing it from proceeding to the substrate. In previous decades another approach was tested by using hydrophobic metal soaps such as calcium or zinc stearate with positive results in relation to the durability of waterproofed mortars [14,15]. Most recently, nano-sized clays have been added to epoxy coatings for metal protection [14]. Nowadays, the sustainable protection of building materials is imperative as an energy saving policy due to climatic changes and energy consuming efficiency. Different modern techniques have been applied in bricks and mortars in order to achieve an efficient result which comprises water repellent properties, high porosity and mechanical resistance to stresses. Polymer creams were applied to bricks and mortars and reduction of damp problems was recorded [16]. By the development of nanotechnology these nano-sized particles were combined with organic components and were used in order to roughen the surface and at the same time reduce the surface free energy achieving super hydrophobic materials [17,18]. Alkoxysilanes and alkoxy polysiloxanes were also a subject of research for many decades [19,20]. In other cases the application of organosiloxane and ethyl-methacrylate copolymers led to disappointing results without improving their hydric properties [21]. It can be seen that the efficiency of water repellent treatment strongly depends on the impregnation depth which will in turn affect the wetting properties of the porous materials [22].

The main negative results of hydrophobic treatments are related to moisture entrapment of humidity in a porous network since the treatment can prevent water to reach the upper surface and evaporate. Additionally, a water-repellent effect is usually reduced by UV-light exposure and generally the effectiveness of a treatment will be decreased by time [23].

Traditionally produced bricks were fired at low temperature (not higher than 900–950 °C) and consequently, they were less resistant and more sensitive to decaying agents such as moisture and salts. Their porosity was high and they were prone to water absorption both naturally and by capillarity [24–27]. In order to maintain the traditional technique and produce compatible bricks which could be used in restoration works, the idea to protect them against deterioration by applying a treatment with solutions by the total immersion technique was studied. It was preferred to use the immersion technique as it could easily and with low cost be embodied as the last stage of an existing production line of traditional brick manufacturing.

The aim of this paper is to present the results of an extensive experimental work performed in low-fired bricks (kilned up to 900 °C). Both traditional water repellent materials such as linseed oil and modern products were used in order to examine their efficiency. The solutions were modified by silica nanoparticles and different tests have been carried out on the treated brick samples.

2. Materials and techniques

The brick samples were cast in 4 × 4 × 4 cm cubes and were dried until no change in weight was observed. Then they were impregnated into the solutions for 2 min. All nano-modified solutions had been subjected to stirring by ultrasounds for 1 h, in order to avoid nanoparticle agglomeration. After impregnation, all the treated samples were left at room conditions to dry for 7 days before any test was carried out. The particle size distribution of the clay used was determined using Scirocco Mastersizer 2000MU (dry phase). Thus 90% of the clay sample was below 94.58 μm, 50% of the sample was below 14.9 μm and 10% was below 3.9 μm. The mineralogical analysis by XRD (Philips PW) showed that the clay is rich in quartz and mica (Fig. 1). The clay was used in 1%w.w. of the solution and was stirred thoroughly with the nanosilica particles. The addition of clay aimed at exploiting its hydrophobic properties and also, at covering the whitening effect caused by the nanosilica particles [22].

Nanosilica was of 14 nm diameter and specific surface was 250 ± 25 m^2/g. It was used in 1.5%w.w. of the solution. The solutions used were:

- Linseed oil (L) and linseed oil with ethyl acetate (ethyl acetate has been used as dissolver to a ratio 1:5 parts per weight with linseed oil) and 1%w.w. silica nanoparticles (LN)
- Silane/siloxane (S) and silane/siloxane with 1%w.w. clay and 1.5%w.w. silica nanoparticles (SN)
- Alkosiloxane (A) and alkosiloxane with 1%w.w. clay and 1.5%w.w. silica nanoparticles (AN)

The tests performed were:

- Capillary absorption according to EN1015-18
- Porosity according to RILEM CPC11.3
- Water drop test by measuring the contact angle (by KSV CAM 200 – Optical Surface Tension/Contact Angle meter instrument)
- Roughness measurements of the surface using Mitutoyo profilometer and recording Ra values which are used widely as one-dimensional roughness parameter and it concerns the arithmetic average of the absolute values
- Karsten tube penetration test (CSTLI7500-TQC)
- Penetration depth by empirical laboratory protocol based on macroscopic and microscopic observations
- Freeze-thaw and salt cycles deterioration tests according to EN12390-2:2002 and EN12370-1999 respectively. The samples were dried until stable weight. Then those samples were tested in salt cycles. They were subjected to 15 cycles in 14%w.w. Na_2SO_4. The samples tested in freeze-thaw test performed 40 cycles from −18 °C to +20 °C. The weight change has been reported as well as macroscopic observation after the end of each test.
- Microscopic examination by SEM (JEOL840A JSM)

In each test untreated samples (recorded as M) were tested for comparison reasons.

3. Experimental results

In Table 1 the results of the physical properties as well as the roughness and the water drop contact angle achieved are reported.

In all cases the porosity and the water absorption tension were lower in relation to the untreated samples but in some cases the values were closer to the reference values. This is the cases in the S and SN solutions. It seems that the silane/siloxane matrix did not cover the pores of the material. The even higher porosity values of the SN solution may be attributed to the presence of clay. The roughness of the treated samples was increased and as a con-

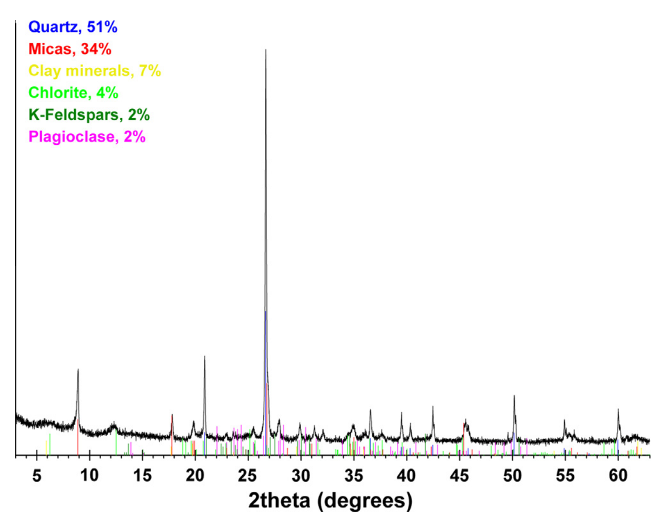

Fig. 1. XRD diagram of the clay used in the modification of the solutions.